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THE FLUTING AND PITTING OF GRANITES
IN THE TROPICS.

(PLATES I-VIII.)

By J. C. BRANNER.

(Read April 4, 1913.)

Fluting is a peculiar minor form of topographic relief, but where it occurs over an area large enough to attract attention, it is a very striking feature.

All geologists are familiar with the fluting of limestones, which is a common phenomenon all the world over. Many fine examples of the fluting of limestones are given in Dr. H. Stille's "Geologische Charakterbilder," 10 Heft, published at Berlin in 1912, in which they are called "Karren."

But the fluting of granites or of other crystalline rocks is, so far as I have been able to learn, confined to tropical, and possibly sub-tropical countries. Two cases that occur on the coast of the state of Pernambuco in Brazil were mentioned by me in a paper on rock decomposition published in 1896.¹ Since that paper was published I have seen in Brazil some very striking examples, and have seen photographs of several others. Good examples are also cited by Max Bauer, who speaks of them as furrows (Rillen).²

¹ J. C. Branner, "Decomposition of Rocks in Brazil," *Bul. Geol. Soc. Amer.*, VII., 280, Rochester, 1896.

² *Neues Jahrbuch f. Mineralogie*, 1898, II., 192, and Plate XI.

The cases mentioned by Bauer occur in granites at Point Larue on the Island of Mahé, one of the Seychelle Islands in the Indian Ocean, about latitude $4^{\circ} 30'$ south, and longitude 55° east.

The most impressive examples of the fluting of crystalline rocks that I have ever seen were found in 1911 near the village of Quixadá in the interior of the state of Ceará, Brazil (Plate I.), latitude $5^{\circ} 5'$ south and longitude $19^{\circ} 20'$ west at an elevation of 180 meters above tide. In the vicinity of Quixadá almost every elevated exposure of the granites shows more or less fluting. Only those of which the best photographs were obtained are shown in the accompanying plates. The hills shown in these pictures are from 100 to 225 meters high, that is above their bases. Efforts to get photographs of the fluting about Quixadá have been only partially successful, as may be seen from the illustrations given with the present paper. Horace E. Williams of the Serviço Geológico do Brazil has sent me a photograph of fluted granites in the Serra de Borborema, 25 kilometers south of Campina Grande in the state of Parahyba.

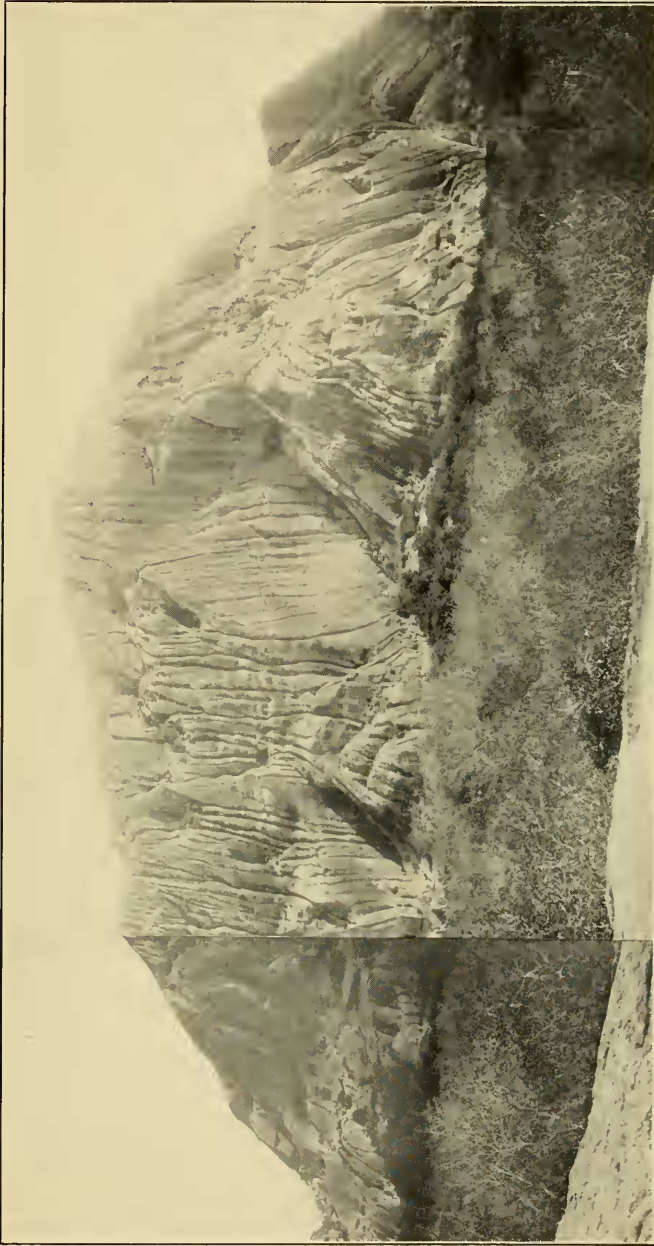
Other cases that have come to my attention occur in the interior of Ceará, and about the famous Itatiáya, the loftiest peak in Brazil, situated in the extreme northwest corner of the state of Rio de Janeiro. Itatiáya has an elevation of 2,994 meters above tide. The fluting of that peak was mentioned to me many years ago by Mr. Derby, the present director of the geological survey of Brazil,³ but I did not then fully realize the extent and amount of it.

Recently I received from Dr. Carlos Moreira, of the National Museum at Rio de Janeiro, some photographs made by him of the Itatiáya peaks together with specimens of the rocks themselves. Dr. Moreira spent some forty-five days on and about that peak, and though his photographs are small, they are clear, and they are the best we have thus far seen of the fluting in that particular region (Plate II.).

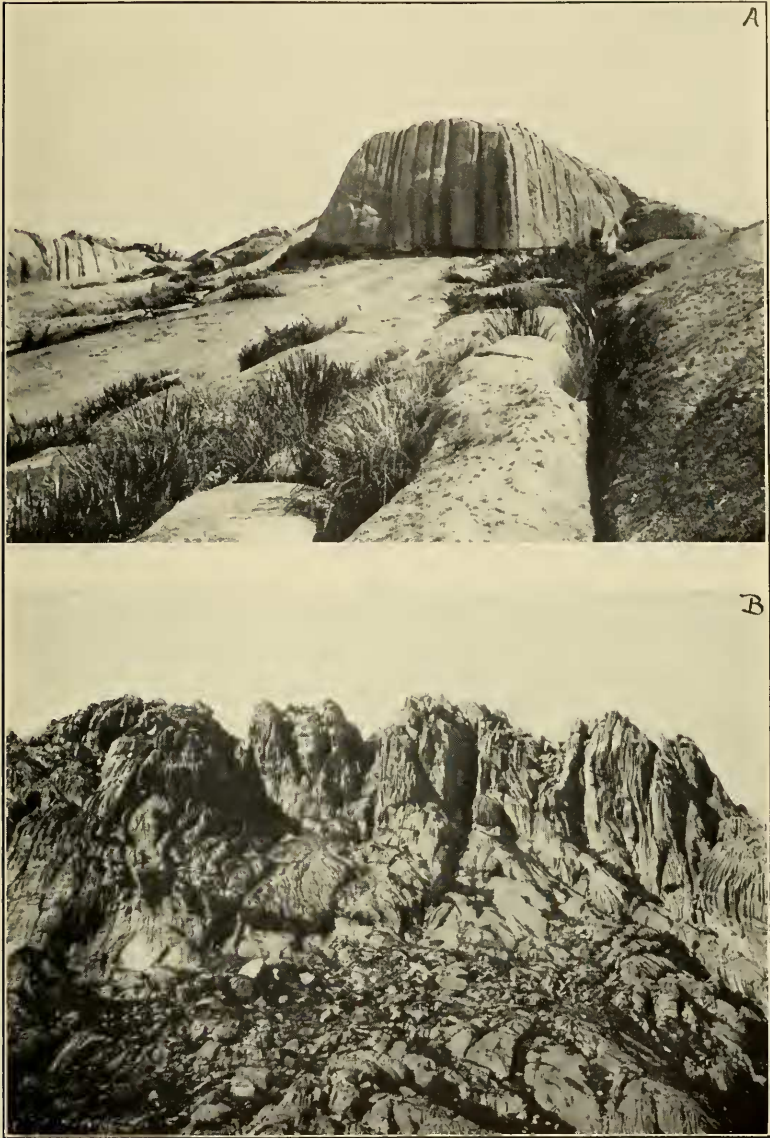
CHARACTERISTICS OF THE FLUTING OF GRANITES.

In the fluting of limestones there is generally left at the crest of

³ *Bul. Geol. Soc. Amer.*, VII., 280, footnote.



Serra Riscada near Quixadá, Estado do Ceará, Brazil. Height of the hill above its base, 226 meters. Inspectoria de Obras Contra as Seccas, phot., 1911.



Fluted syenite on and about the summit of Itatiáya, State of Rio de Janeiro, Brazil. Carlos Moreira, phot.

the miniature watersheds characteristic sharp, but somewhat ragged, combs of the rock. Between these divides are narrow, round-bottomed furrows or grooves that run down the slopes of the rocks by the shortest routes. These shallow grooves suggest the marks made by the fingers when drawn across a mass of plastic clay or putty. The furrows or grooves in limestone, however, are, as a rule, only an inch or so in diameter; that is the fluting of limestones is not usually on a large scale.

The illustrations given in Dr. Stille's "Geologische Charakterbilder," Heft 10, however, show flutings in limestones of various kinds, and some of these have unusually large furrows.

The fluting of granites and other coarsely crystalline rocks, however, is on a large scale, and the grooves have only a remote resemblance to those on limestone surfaces. The fluted surfaces necessarily appear only where the rock is entirely bare of soil. For the most part the furrows start at the summit of the exposed rock or as near it as possible, and run straight down the rock slopes by the shortest possible routes. Those seen at and about Quixadá reach a maximum depth of nearly two meters measured at right angles to the general surface of the rock masses. This takes no account of the ordinary gullies cut by the larger streams. Instead of having sharp combs separating the drainage areas of the different furrows, the divides or miniature watersheds on the granite surfaces are always rounded. But while the surfaces of the granite rocks are rounded in general outline, they are quite rough, this roughness being caused by the coarse crystals standing out boldly over the entire exposed rock surface. About Quixadá the rocks contain but little quartz, and feldspars are the minerals that produce this roughness of surface.

CALDRON-LIKE PITS.

In the Quixadá region the fluted rocks are covered here and there with great rounded caldron-like pits some of which are associated directly or indirectly with the fluting. These pits are shown in some of the accompanying illustrations (Plates III., IV., V.). They are not usually very deep, that is, they seldom exceed a depth of two meters

when isolated, and they reach a diameter of two meters or more, though they are generally not so wide. The fluting sometimes has the appearance of originating in these caldrons, but this seems to be due to the water overflowing and cutting notches in the rims on one side and thus merging the pits and the fluting into each other. In some cases I have seen a series of these pits in a nearly vertical row

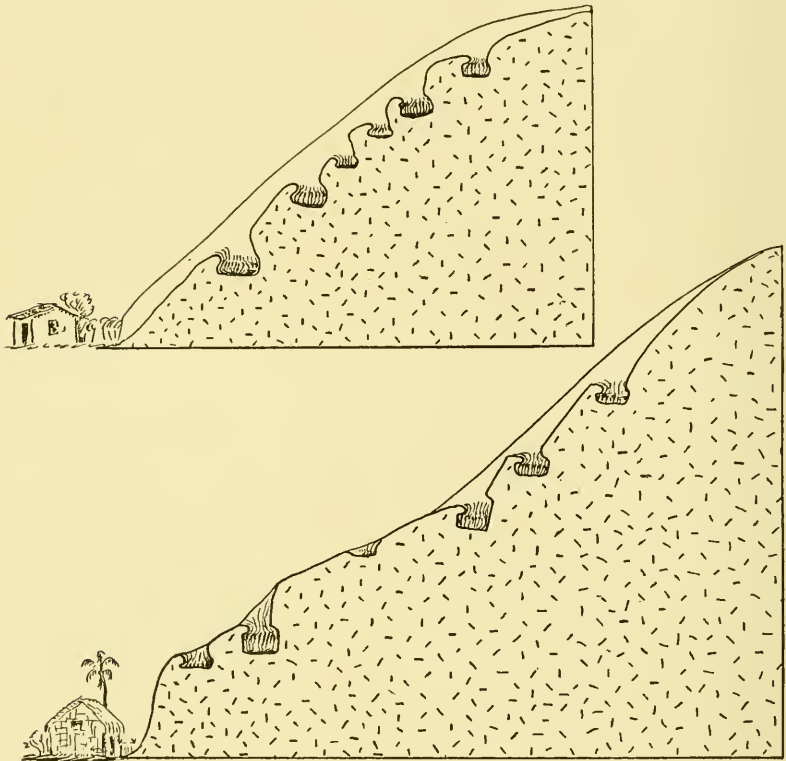


FIG. 1. Composite sections down the pitted and fluted rock surfaces at and about Quixadá showing the general forms of the caldrons.

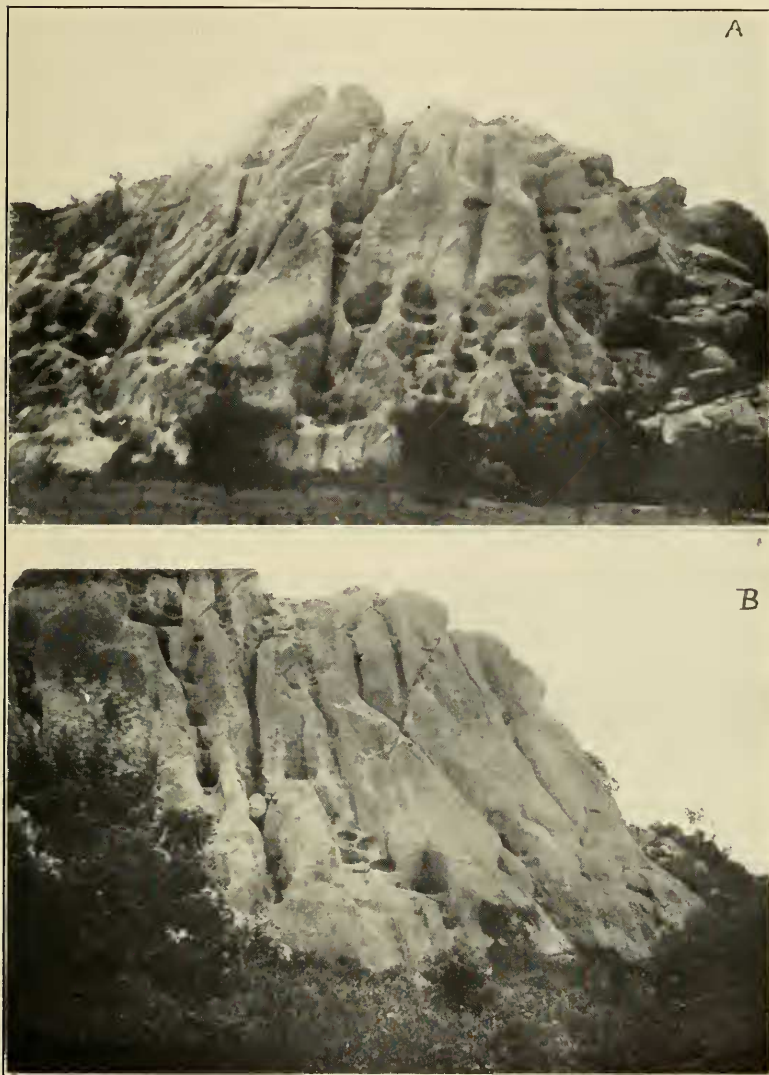
and connected by a furrow that gives the whole the appearance of a great irregular staircase mounting the hill (Fig. 1).

These caldrons are very abundant in some of the rocks, while in others they do not appear at all. They occur on the tops of mountains, hills, or bosses, on the sides and at the bases; they are mostly



A. Fluted and pitted hills at kilometer 183, near Quixadá, Ceará. Waring, phot., 1912.

B. Fluted and pitted hills at kilometer 183½, near Quixadá, Ceará. Waring, phot., 1912.



A. Pitted syenite east of the railway near Quixadá, Ceará. Waring, phot., 1912.

B. Pitted granodiorite near Quixadá. E. Leib, phot., 1911.

